



A U S T R A L I A N T R A N S P O R T S A F E T Y B U R E A U

ROAD SAFETY RESEARCH REPORT
OR 23

A blurred, grayscale photograph of a road scene, showing a car in the distance and road markings. The image is out of focus, creating a sense of motion or depth.

ROAD SAFETY

Fatigue-related crashes:

*An analysis of fatigue-related crashes
on Australian roads using an
operational definition
of fatigue*

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Department of Transport and Regional Services

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Fatigue-related crashes:

An analysis of fatigue-related crashes on Australian roads using an operational definition of fatigue.

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Abstract

In recent years fatigue has been considered a primary contributory factor in road crashes. However, precise identification of fatigue-related crashes is hindered by the absence of a universally accepted definition of fatigue. Furthermore, it is difficult to quantify the level of driver fatigue due to difficulties in objectively measuring the degree of fatigue involved in a crash. To overcome these obstacles the Australian Transport Safety Bureau (ATSB) has proposed an operational definition of a fatigue-related crash. The definition is based on a set of well-researched selection criteria and uses crash characteristics routinely collected by different traffic authorities. This definition should be useful in monitoring fatigue-related crashes and gauging trends over time or between regions. Using the ATSB operational definition, the proportion of fatal crashes involving driver fatigue increased initially in the early 1990s, (14.9 per cent in 1990 to 18.0 per cent in 1994), and then decreased in the late 1990s (16.6 per cent in 1998). The study suggests that the operational definition provides a practical and useful index of the relative incidence of fatigue-related crashes.

Keywords

Driver fatigue, fatal crashes, operational definition, surrogate measure, articulated trucks.

NOTES:

- (1) ATSB research reports are disseminated in the interests of information exchange.
 - (2) The views expressed are those of the author and do not necessarily represent those of the Commonwealth Government.
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ABBREVIATIONS

ABS	Australian Bureau of Statistics
ATSB	Australian Transport Safety Bureau
EPDFS	Expert Panel on Driver Fatigue and Sleepiness
FEG	Fatigue Expert Group
FORS	Federal Office of Road Safety
HORSCOCTA	House of Representatives Standing Committee on Communication, Transport and the Arts
NRTC	National Roads Transport Commission
RTA	New South Wales Roads and Traffic Authority
UK	United Kingdom
USA	United States of America

This report examines a proposed operational definition of fatigue, and the occurrence and characteristics of fatigue-related road crashes within Australia as identified by the operational definition.

Fatigue represents a significant social and economic cost to the community in relation to road crashes, especially fatal road crashes. Fatigue-related crashes are often more severe than other crashes as drivers' reaction times are often delayed or drivers have not employed any crash avoidance manoeuvres. However, the identification of fatigue-related crashes is hindered by the absence of a universally accepted definition of fatigue. Furthermore, it is difficult to quantify the level of driver fatigue due to the difficulties in objectively measuring the degree of fatigue following a crash.

The Australian Transport Safety Bureau (ATSB) has proposed an operational definition of a fatigue-related road crash that would provide a common, objectively based methodology. This definition should be useful in monitoring fatigue-related crashes and gauging trends over time or between regions. The definition is based on a set of well-researched selection criteria and uses crash characteristics routinely collected by different traffic authorities.

The criteria for the operational definition implemented in this report included single vehicle crashes that occurred during 'critical times' (midnight-6am and 2pm-4pm), and head-on collisions where neither vehicle was overtaking at the time of the crash. Excluded were crashes that occurred on roads with speed limits under 80 km/h, or involved pedestrians or unlicensed drivers or drivers with high levels of alcohol (blood alcohol concentration over 0.05g/100ml).

Using this criteria, this study found that 16.6 per cent of fatal crashes in 1998 involved driver fatigue. When comparing among the States and Territories, the Northern Territory had the highest rate of fatigue-related crashes per 100 million vehicle kilometres travelled (0.66). However, within individual States and Territories, New South Wales had the highest percentage of fatal crashes involving driver fatigue (22.0 per cent). The study also found that between 1990 and 1998 the proportion of fatal crashes involving driver fatigue increased from 14.9 per cent in 1990 to 18.0 per cent in 1994, after which there was a decline to 16.6 per cent in 1998. This trend was also observed when the number of fatigue-related crashes was worked as a proportion of all fatal crashes 80km/h or over. This was done to take into account the fact that the number of fatal crashes occurring in speed zones of 80km/h or over increased throughout the 1990s and that roads have also been re-zoned over this time period.

The operational definition identified a relationship between the time and type of fatigue-related crashes. More single vehicle crashes occurred in the early morning (midnight-6am) than the afternoon (2pm-4pm). However, the incidence of head-on crashes was highest between midday and 6pm and lowest between midnight and 6am, this relationship may be related to traffic densities. That is, higher traffic densities during the day would increase the likelihood of fatigue-related crashes involving multiple vehicles in head-on collisions and, conversely, lower traffic densities during the early morning would increase the likelihood of fatigue-related crashes involving single vehicles.

Some of the findings of this study were similar to other studies in that the operational definition identified a higher number of male fatigued drivers/riders than female, and more fatigued drivers/riders under 29 years of age compared with older age groups. The operational definition and other studies also found that most early morning fatigued drivers/riders were less than 29 years of age, and fatigued drivers/riders over 50 years of age were involved in more afternoon crashes than in early morning crashes.

There also appeared to be a relationship between the age of the fatigued driver/rider and the type of fatigue-related crash (single vehicle or head-on). Single vehicle crashes involved a higher proportion of fatigued drivers/riders under 29 years of age compared with head-on crashes. However, fatigued drivers/riders over 50 years of age were involved in more head-on crashes. This relationship may be linked to the time of crash. That is, single vehicle crashes are more likely to occur in the early morning and early morning crashes are more likely to involve fatigued drivers/riders under 29 years of age. Therefore, single vehicle crashes involve more fatigued drivers/riders under 29 years of age. A similar argument could explain the relationship between older fatigued drivers/riders and head-on crashes.

Using the operational definition, 29.9 per cent of fatal articulated truck crashes in 1998 involved driver fatigue, which was almost twice the proportion of all fatal crashes involving fatigue (16.6 per cent). However when speed limits were controlled for, by only including those crashes occurring at crash sites with speed limits of 80km/h or over, the difference between articulated truck crashes and all crashes was smaller. That is, in 1998, 34.5 per cent of fatal articulated truck crashes in speed zones of 80km/h or over involved fatigue, whilst 24.9 per cent of all fatal crashes involved fatigue.

The operational definition also found that the proportion of fatigue-related articulated truck crashes between 1990 and 1998 increased from 31.0 per cent in 1990 to 38.6 per cent in 1994, and this was followed by a decrease to 29.9 per cent 1998. Similar trends were also observed when speed zones were controlled, with an initial increase in the proportion of fatigue-related crashes between 1990 and 1994, followed by a decrease till 1998.

Although fatigue is more highly represented in articulated truck crashes, this does not necessarily imply that the truck driver was the fatigued driver in a crash involving more than one vehicle. The fatigued driver in a head-on crash was identified by observing which vehicle had driven onto the wrong side of the road. Therefore, in head-on fatigue-related crashes involving an articulated truck, truck drivers were estimated to be the fatigued driver in only 16.8 per cent of crashes, whilst passenger car drivers were fatigued in 66.0 per cent of crashes.

The identification of fatigue-related crashes by the operational definition was compared with fatigue-related crashes identified by coroners/police. While researchers generally acknowledge that coroners/police underestimate the incidence of fatigue, it was the only measure available for comparison in this report. The operational definition compared relatively well; however, two limitations and possible modifications for the operational definition were highlighted. Firstly, nearly two-thirds of crashes identified as fatigue-related by coroners/police, but not by the operational definition, were excluded because they were single vehicle crashes that did not occur during the critical time periods. Secondly, just over a third of crashes identified as fatigue-related by the operational definition, but not by the coroners/police, had been attributed to speed, drugs, or drugs-and-alcohol by coroners/police. This may suggest that the operational definition should

be modified to exclude speed and drug related crashes, and extend the critical time periods for single vehicle crashes. However, excluding drug and speed related crashes may reduce the objectivity of the operational definition and the ability to consistently implement the definition across various traffic authorities. For instance the identification of speed involvement can vary between different traffic authorities, and not all drivers involved in fatal crashes are tested for drugs. Furthermore, extending the critical time periods may lead to an increase in the number of crashes falsely identified as fatigue-related. Clearly, more analysis is needed before the definition is modified.

In conclusion, while the operational definition may include some crashes that are not fatigue-related and exclude others that are, it nevertheless provides a practical and useful index of the relative incidence of fatigue-related crashes.

This report examines the ATSB proposed operational definition of fatigue and the occurrence and characteristics of fatigue-related road crashes within Australia.

3.1 Defining fatigue

The phenomenon of fatigue, while heavily researched, does not have a universally accepted definition. Therefore, the term fatigue, as used in this report, refers to a combination of symptoms, such as impaired performance and subjective feelings of drowsiness, as well as contributory factors, such as prolonged activity, insufficient sleep and disruption of circadian rhythms (FEG, 2001). Using this definition, the involvement of fatigue in a road crash can range from falling asleep at the wheel to inattention (HORSCOCTA, 2000).

The general consensus is that the three main determinants of fatigue are:

- lack of sleep
- time of day or circadian factors
- time spent performing a task (Hartley, Penna, Corry and Feyer, 2000; Williamson, Feyer, Friswell and Finlay-Brown, 2000).

Individual factors such as age, physical fitness and medical condition (for example, sleep disorders) also affect the incidence of fatigue (HORSCOCTA, 2000).

3.1.1 Lack of sleep

Sleep is an important physiological function. When people do not obtain enough sleep they build up a 'sleep debt'. Sleep debt refers to the difference between the minimum amount of sleep needed to maintain appropriate levels of alertness and performance, and the actual amount of sleep obtained (Rosekind, 1999).

Research has found that as little as two hours sleep loss on one occasion can result in degraded reaction time, cognitive functioning, memory, mood and alertness. Cumulative sleep debt significantly reduces alertness and performance, especially on attention based tasks such as driving (Rosekind, 1999; Dinges, 1995; Hartley and Arnold, 1995; EPDFS, 1997).

3.1.2 Time of day

Humans possess a neurobiological based sleep-wake cycle called a circadian rhythm or body clock (EPDFS, 1997; Folkard, 1997). Research has shown that there are two periods during the 24 hour circadian cycle where the level of sleepiness is high. The first period is during the night and early morning, and the second is in the afternoon (Hartley et al, 2000). During these periods of sleepiness, many functions (eg. alertness, performance and subjective mood) are degraded (Rosekind, 1999).

The effect of the circadian rhythm in road crashes was demonstrated by Pack et al (1995) who analysed North Carolina road crash data. This study found that fatigue-related crashes corresponded to circadian variation in sleepiness, with a major peak during the night and a secondary peak mid afternoon.

Wylie (1996) examined the loss of alertness and degraded performance of 80 male truck drivers from the USA and Canada. One method used in this study involved continuous video monitoring of a driver's face for eyelid droop and other fatigue induced facial

expressions. It found that drowsiness peaked between late evening and dawn. The study also found that 'time of day' was the most consistent factor influencing driver fatigue.

3.1.3 Time on task

Prolonged physical activity without rest leads to muscular fatigue. Similarly, a prolonged mental workload without rest will lead to reduced alertness and disinclination to continue the effort (Grandjean, 1988).

Research based on driving tasks has shown that the length of time on a task affects performance. As time spent on a task is increased, the level of fatigue is increased, reaction time is slowed, vigilance and judgement is reduced and the probability of falling asleep during the task is increased (EPDFS, 1997; HORSCOCTA, 2000).

3.1.4 Surrogate measures of fatigue

As previously mentioned, the role of fatigue in road crashes is difficult to measure due to the absence of an objective test for the level of fatigue or sleepiness of drivers involved in crashes (Connor, Whitlock, Norton and Jackson, 2001). Nor are there definitive criteria for establishing the level of fatigue that leads to crashes.

Crash outcomes and crash data collection methods also complicate the identification of fatigue-related crashes. In fatal crashes there may be no surviving witnesses to give an account of the crash, or the surviving driver may be influenced by possible legal consequences of the crash. The crash itself is also sufficient to alter arousal levels and may eliminate any evidence of impairment due to fatigue. In addition, crash investigations do not routinely collect information on length of time spent driving, details of rest breaks or previous work and rest schedules of the drivers involved.

Current knowledge of fatigue-related crashes is based on subjective evidence or surrogate measures of fatigue due to problems previously mentioned with identifying fatigue-related crashes. A level of confidence regarding surrogate measures has arisen from the range of studies that have reached similar conclusions on what defines a fatigue-related crash (EPDFS, 1997).

In the United Kingdom, Horne and Reyner (1995) identified fatigue-related crashes using the following criteria:

- vehicle ran off the road and/or collided with another vehicle or object;
- absence of skid marks or braking;
- driver saw the point of run-off or the object hit prior to the crash;
- witnesses reported lane drifting prior to the crash; and
- excluded are those instances where another cause may have been the primary factor, eg. mechanical defect, speeding, excess alcohol, bad weather (Horne and Reyner, 1995).

Similarly in the United States, the Expert Panel on Driver Fatigue and Sleepiness (1997) characterised a fatigue-related crash by the following:

- occurred late at night, early morning or mid-afternoon;
- resulted in higher than expected severity;
- involved a single vehicle leaving the roadway;

- occurred on a high speed road;
- driver did not attempt to avoid the crash; and
- driver was the sole occupant in the vehicle.

Some Australian States also use surrogate measures, in addition to police reporting, to identify fatigue (see Appendix A).

The ATSB operational definition of a fatigue-related crash employs some of the criteria used in the United States, the United Kingdom and some Australian States.

3.1.5 **ATSB operational definition of fatigue**

The operational definition of a fatigue-related crash implemented in this report:

- includes single vehicle crashes that occurred during ‘critical times’ (midnight–6am and 2pm–4pm);
- includes head-on collisions where neither vehicle was overtaking at the time;
- excludes crashes that:
 - occurred on roads with speed limits under 80 kilometres per hour;
 - involved pedestrians;
 - involved unlicensed drivers;
 - involved drivers with high levels of alcohol (blood alcohol over 0.05g/100ml).

By analysing crash investigation reports, research has shown that fatigue-related crashes generally include single vehicle crashes in which the vehicle drifted off the road, or head-on collisions in which the vehicle drifted onto the wrong side of the road but was not overtaking at the time of the crash (Haworth and Rechnitzer, 1993; Pack et al 1995). Haworth and Rechnitzer (1993) found that close to 75 per cent of fatigue crashes, identified by coroners, involved a single vehicle drifting off the road, and head-on (non-overtaking) crashes accounted for 22 per cent of fatigue-related crashes.

Selection of the two critical crash periods reflects the influence of circadian rhythms on levels of fatigue and crash risk. As mentioned previously, crash risk is highest in the early hours of the morning, with a secondary peak in the early afternoon corresponding to the ‘post-lunch dip’ (Folkard, 1997; Hartley, 2000; Pack et al, 1995).

Including only those crashes where the speed limit was 80km/h or greater automatically includes crashes on rural highways. This is important because research, such as Haworth and Rechnitzer’s (1993) analysis of coroner reports, found that fatigue-related crashes are more common on rural highways than on urban and rural roads. One reason for this is that average trip lengths are likely to be longer on rural highways and inattention and drowsiness are more readily triggered by constant speed and monotony in the task and surroundings (Haworth and Rechnitzer, 1993; EPDFS, 1997; Pack et al, 1995).

Crashes where a driver was found to possess high levels of blood alcohol concentration (greater than 0.05g/100ml) are excluded from the fatigue crash definition as high levels of alcohol disrupt a driver’s perceptual-motor coordination, and increase the risk of being involved in any type of crash (Haworth and Rechnitzer, 1993). Research has also shown that low levels of alcohol in combination with factors that contribute to fatigue, such as sleep loss and circadian rhythms, can increase the risk of being involved in

fatigue-related crashes (EPDFS, 1997). Roehrs et al (1994) in EPDFS (1997) found that in a driving simulation study, people driving after 4 hours of sleep with low alcohol levels produced a greater number of errors (driving off the road) compared with subjects driving after 8 hours of sleep with low alcohol levels.

Crashes involving pedestrians are also excluded from the operational definition because of the nature of most fatigue crashes. That is, most fatigue-related crashes occur on rural highways, whereas most pedestrian crashes occur in urban, residential areas. In 1992, only 15 per cent of pedestrian crashes occurred in rural areas (FORS, 1996). In addition, pedestrians rather than vehicle operators are more often responsible for the pedestrian crashes. In 1992, 74 per cent of pedestrians involved in fatal crashes were primarily responsible for the crash and a further eight per cent were partially responsible (FORS, 1996). Therefore, driver impairment due to fatigue is less likely to be the primary causal factor involved.

Crashes involving unlicensed drivers have been excluded from the operational definition, as unlicensed drivers are known to be associated with a number of high-risk behaviours, such as speeding, alcohol and not wearing a seatbelt (FORS, 1997). Therefore, while fatigue may or may not be a factor, it is more likely to be a secondary factor in the crash.

3.2 Fatigue-related crashes

3.2.1 Fatigue-related crashes in Australia

The estimation of the proportion of crashes attributable to driver fatigue varies from five per cent to 50 per cent. The difficulty in measuring fatigue contributes to this variation. However, most experts estimate that 20 per cent to 30 per cent of fatal road crashes could result from driver fatigue (HORSCOCTA, 2000). A proportion of these crashes involves drivers falling asleep at the wheel. Additionally, an even higher proportion of crashes involves inattention due to fatigue (Hartley, Penna, Corry and Feyer, 2000).

The ATSB fatality crash database identified fatigue to be a contributory factor in seven per cent of all fatal crashes in Australia in 1998. The identification of fatigue is based on coroner and police reports. However, these reports are recognised as under estimating the incidence of fatigue as coroners do not judge fatigue to be a contributory factor unless there is strong evidence (direct or circumstantial) that the driver was asleep at the time of the crash (Haworth, 1998). In addition, Buxton, Hartley and Buxton (2001) note that police may not be sufficiently trained to detect the incidence of fatigue and may have neither the time nor the resources to examine individual crashes to the extent required.

3.2.2 Heavy truck involvement in fatigue-related crashes

The Fatigue Expert Group (2001) noted three reasons why fatigue is an important road safety issue for heavy truck drivers and operators. Firstly, there is public concern specifically on truck safety. Truck crashes are often more severe than non-truck crashes and in multiple vehicle crashes the risk of being injured is greater for the non-truck occupants. Secondly, fatigue is proportionally more significant as other risk factors such as drink-driving, excessive speeding and other risky behaviours are less common where crashes are attributed to the truck drivers. Finally, fatigue is an occupational health and safety issue as truck drivers can spend a considerable amount of time on the road as part

of the job. An articulated truck's average vehicle kilometres travelled per year is nearly six times higher than the average kilometres travelled by a passenger vehicle (Survey of Motor Vehicle Use, 1999). Therefore, a truck driver's level of exposure is greater than that of a passenger vehicle driver.

The nature of the transport industry may also contribute to the incidence of fatigue-related crashes. A report by the Western Australian Department of Transport on fatigue management for commercial truck drivers noted that within the transport industry 'work practices include working long hours, prolonged night work, irregular hours, little or poor sleep and early starting times' (WA Department of Transport, 1998, p5). This report also noted that many truck drivers work more than 12 hours per day with at least 60 per cent of this time spent driving. Therefore, these long working hours, reduced sleep and built-up sleep debt may increase the risk of being involved in a fatigue-related crash (WA Department of Transport, 1998). Truck drivers themselves acknowledge that fatigue is a problem within the transport industry and most drivers have reported feeling fatigued at least occasionally whilst driving. They also feel fatigue negatively affects their driving performance with slower reaction times, poor steering and poor gear selection and change (Williamson et al, 1992).

There has been a lot of research into estimating the proportion of truck crashes involving fatigue, however again there are problems with identifying fatigue-related crashes. Research conducted by Haworth, Heffernan and Horne (1989) used two methods for identifying fatigue (coroners' reports and judgements made by the authors based on crash circumstances) to examine whether a truck was involved in a fatigue-related crash and the proportion of such crashes attributable to the truck driver. They found that between nine per cent and 20 per cent of fatal truck crashes involved fatigue, with three per cent to seven per cent attributable to truck driver fatigue. This research highlights the notion that whilst trucks are involved in fatigue-related crashes it is not necessarily the truck driver who is fatigued.

3.2.3

Fatigued drivers

Knipling and Wang (1994) examined USA statistics between 1989–93 and found that age and sex of drivers were strongly related to involvement in fatigue-related crashes. In 1990, 77 per cent of fatigued drivers were male and 62 per cent of fatigued drivers were under 30 years of age. When comparing vehicle kilometres travelled, male drivers were nearly twice as likely to be involved in fatigue-related crashes than female drivers. Drivers under 30 years of age were four times more likely to be involved in fatigue crashes than drivers over 30 years of age (Knipling & Wang, 1994).

The time of day the fatigue-related crash occurs also strongly correlates to the age of the driver. Young drivers (25 years of age and younger) and drivers between 26–45 years of age are more likely to be involved in fatigue-related crashes during night time hours. Older drivers (65 years of age and older) are more likely to be involved in fatigue-related crashes during the mid-afternoon (EPDFS, 1997). These trends may be related to lifestyle. That is, more young drivers are on the roads in the early hours of the morning than any other age group and older drivers are more likely to drive in the mid-afternoon (Horne and Reyner, 1995). Older drivers are also more likely to be involved in afternoon fatigue-related crashes because as people grow older the 'post-lunch' dip in performance becomes more apparent and increases the risk of fatigue (Horne and Reyner, 1995).

4 METHOD

4.1 Data sources

For this report the ATSB fatality crash databases (1990, 1992, 1994, 1996, 1997 and 1998) were used. The information in these databases is based on police and coroner reports on fatal road crashes.

ABS publications, *Australian Demographic Statistics* (Catalogue Number 3101.0) and *Survey of Motor Vehicle Use* (Catalogue Number 9208.0) were used to derive fatal crash and fatality rates per 100 000 population and 100 million vehicle kilometres travelled respectively. Unpublished ABS data derived from the *Survey of Motor Vehicle Use* were also used to calculate rates per 100 million vehicle kilometres travelled by age and sex.

4.2 Procedure

Crashes were identified as fatigue-related based on a step-wise selection process. The steps are listed below:

First,

- exclude all crashes where the driver had a blood alcohol concentration (BAC) greater than 0.05g/100ml
- exclude all crashes involving any unlicensed drivers or unlicensed motorcycle riders
- exclude all crashes involving a pedestrian
- exclude all crashes where the speed limit is less than 80km/h.

Then,

- include all head-on crashes where the vehicle was not overtaking at the time
- include all single vehicle crashes that occurred between midnight and 6am, and between 2pm and 4pm.

5

RESULTS

5.1 Fatigue-related fatal crashes

In 1998, 16.6 per cent of fatal crashes and 19.6 per cent of fatalities in Australia were identified as fatigue-related by the operational definition.

New South Wales had the most fatigue-related fatal crashes (97) and the highest proportion of fatigue-related fatal crashes (22.0 per cent) (see table 1).

Table 1:
Fatal crashes by State/Territory and fatigue involvement, Australia, 1998

<i>State/Territory</i>	<i>Fatigue</i>		<i>Non-fatigue</i>		<i>Total</i>
	<i>Number</i>	<i>Per cent</i>	<i>Number</i>	<i>Per cent</i>	
New South Wales	97	22.0	343	78.0	440
Victoria	55	15.6	297	84.4	352
Queensland	42	16.7	210	83.3	252
South Australia	19	13.1	126	86.9	145
Western Australia	18	9.2	178	90.8	196
Northern Territory	10	16.9	49	83.1	59
Tasmania	7	14.9	40	85.1	47
Australian Capital Territory	3	15.0	17	85.0	20
Australia	251	16.6	1260	83.4	1511

Table 2 shows that the Northern Territory had the highest rate of fatigue-related fatal crashes per 100 million vehicle kilometres travelled (0.66) and the Australian Capital Territory had the lowest rate (0.10).

Table 2:
Fatal crashes per 100 million vehicle kilometres travelled^a by State/Territory and fatigue involvement, Australia, 1998

<i>State/Territory</i>	<i>Fatigue</i>	<i>Non-fatigue</i>
New South Wales	0.18	0.62
Victoria	0.11	0.60
Queensland	0.14	0.72
South Australia	0.14	0.93
Western Australia	0.11	1.05
Northern Territory	0.66	3.22
Tasmania	0.16	0.91
Australian Capital Territory	0.10	0.56
Australia	0.14	0.73

^a 100 million vehicle kilometres travelled by State/Territory of registration at 31 July 1998, ABS catalogue 9208.0

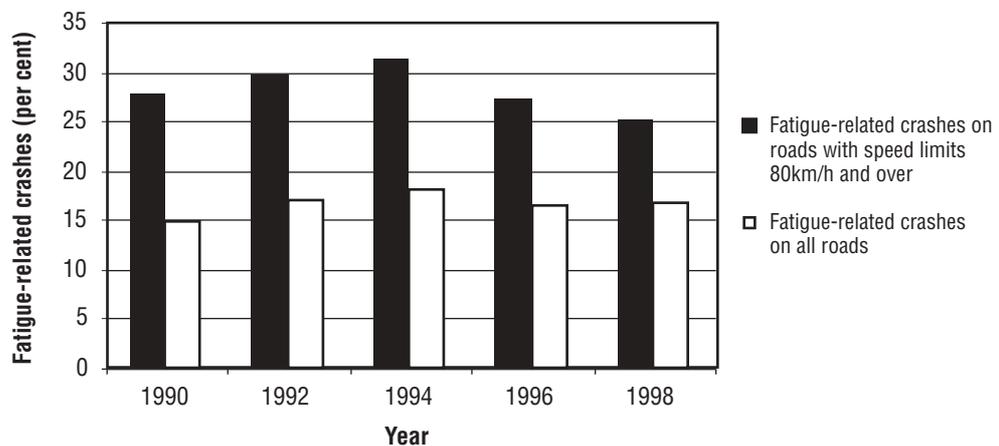
5.2

General trends, 1990 to 1998

Between 1990 and 1998, the proportion of fatal crashes overall involving driver fatigue fluctuated, ranging from a low of 14.9 per cent in 1990 to a high of 18.0 per cent in 1994 (see fig. 1).

Figure 1 also shows the proportion of fatigue involvement in fatal crashes that occurred in speed zones of 80km/h or over. The reason for controlling for speed zones is because the proportion of fatal crashes occurring in speed zones of 80km/h and over has increased significantly over the last decade and roads have also been re-zoned over this period. These factors may artificially influence fatigue trends over time. However, even when speed zones were controlled for, the time series followed a similar trend to when speed zones were not controlled. That is, there was an initial increase in the proportion of fatigue-related crashes from 27.7 per cent in 1990 to 31.2 per cent in 1994 and then a decrease to 24.9 per cent in 1998 (see fig. 1).

Figure 1:
Fatigue-related crashes as a proportion of all fatal crashes and fatal crashes that have occurred on roads with speed limits 80km/h and over, 1990 to 1998

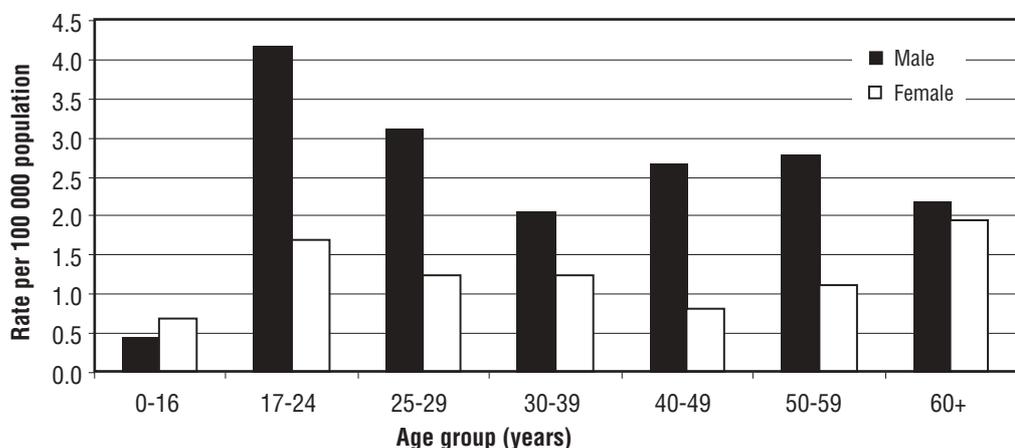


5.3

Fatigue-related fatalities

Figure 2 shows that most fatigue-related fatalities occurred in the male population, and for road users overall those aged between 17 and 24 years.

Figure 2:
Fatigue-related crashes per 100,000 population^a by age and sex, Australia, 1998



^a 100,000 population at June 1998, ABS catalogue 3101.0

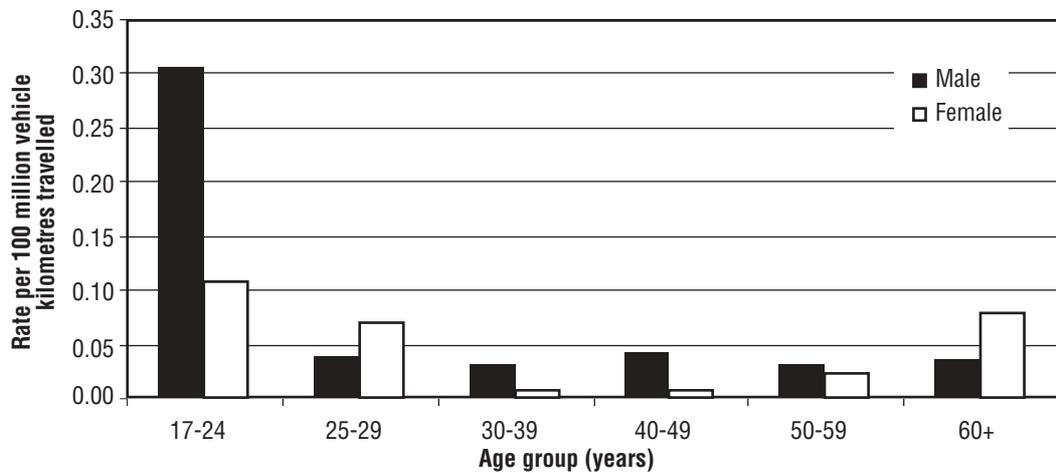
5.4

Characteristics of fatigued drivers/riders

Of fatigued drivers/riders involved in single vehicle crashes:

- 75.5 per cent were male
- 35.1 per cent were young people between 17 and 24 years of age
- 9.6 per cent were aged over 60 years
- when distance driven was accounted for, fatigued male drivers/riders between 17 and 24 years of age recorded the highest rate of crash involvement (see fig. 3)
- 70.2 per cent were driving passenger cars at the time of the crash.

Figure 3:
Fatigued driver/riders involved in fatal single vehicle crashes per 100 million vehicle kilometres travelled^a by age and sex, Australia, 1998



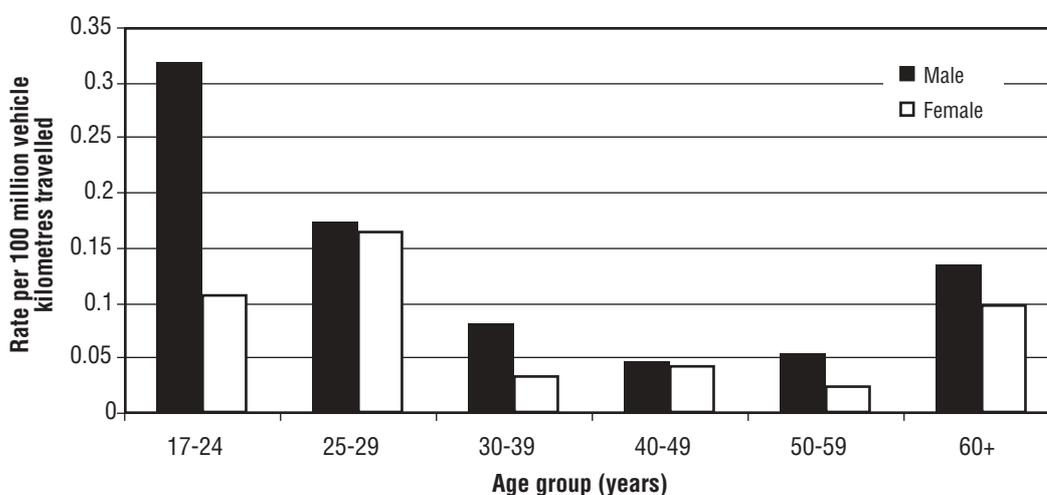
^a 100 million vehicle kilometres travelled, 1998, unpublished ABS data

The fatigued driver in a head-on crash was identified by observing which vehicle had violated the other vehicle's right of way, in other words which vehicle was on the wrong side of the road.

Therefore, of fatigued drivers/riders involved in head-on crashes:

- 72.6 per cent were male
- 21.7 per cent were young people between 17 and 24 years of age
- 22.3 per cent were aged over 60 years
- when distance driven was accounted for, fatigued male drivers/riders between 17 and 24 years of age recorded the highest rate of crash involvement (see fig. 4)
- 77.1 per cent were driving passenger cars at the time of the crash.

Figure 4:
Fatigued driver/riders involved in fatal head-on crashes per 100 million vehicle kilometres travelled^a by age and sex, Australia, 1998



^a 100 million vehicle kilometres travelled, 1998, unpublished ABS data

5.5

Time of single vehicle fatigue-related crashes

The selection criteria identifies two critical time periods for single vehicle crashes: early morning (midnight to 6am) and afternoon (2pm to 4pm).

In 1998, the proportion of fatigue-related crashes that only involved a single vehicle was calculated as 37.5 per cent, of which:

- 42.6 per cent occurred during the afternoon
- 57.4 per cent occurred during the early morning.

Broken down into an average hourly rate of fatigue-related crashes, there were:

- twenty crashes per hour in the afternoon period
- nine crashes per hour in the early morning period.

The relationship between sex and time of crash indicated:

- females were involved in more afternoon crashes
- males were more often involved in early morning crashes (see table 3).

Table 3:
Fatigued drivers/riders involved in fatal single vehicle crashes by sex and time of crash, Australia, 1998

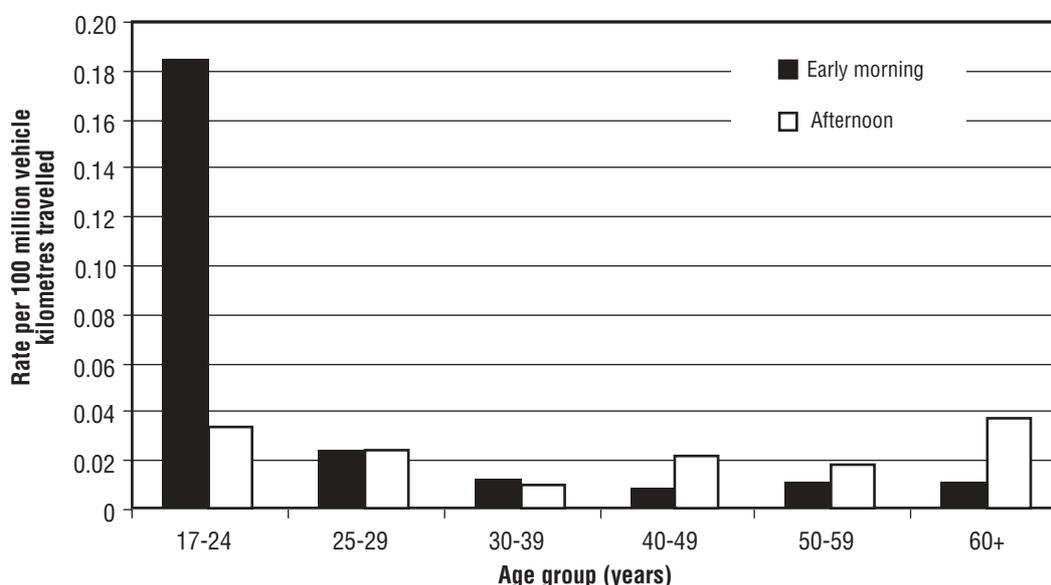
Sex	Time of crash		Total
	Early morning^a	Afternoon^b	
Male	44	27	71
Female	7	12	19
Unknown	3	1	4
Total	54	40	94

^a Early morning = midnight to 6am
^b Afternoon = 2pm to 4pm

In single vehicle fatigue-related crashes:

- young drivers/riders (17–24 years of age) were involved in over five times as many early morning crashes as afternoon crashes
- older fatigued drivers/riders (60 years of age and older) were involved in over three times as many afternoon crashes as early morning crashes
- when distance driven was taken into account
 - fatigued drivers/riders between 17 and 24 years of age were involved in significantly more early morning crashes compared with all other age groups
 - fatigued drivers/riders over 60 years of age were involved in more afternoon crashes compared with all other age groups (see fig. 5).

Figure 5:
Fatigued drivers/riders involved in fatal single vehicle crashes per 100 million vehicle kilometres travelled^a by time of crash and age, Australia, 1998



^a 100 million vehicle kilometres travelled, 1998, unpublished ABS data

5.6 Time of head-on fatigue-related crashes

Head-on, non-overtaking collisions can occur at any time of day and still be identified as fatigue-related by the operational definition.

Of all fatigue-related crashes, 62.5 per cent were head-on collisions with the majority occurring during daylight hours:

- 78.3 per cent occurred between 6am and 6pm
 - 29.9 per cent occurred between 6am and midday
 - 48.4 per cent occurred between midday and 6pm
- 21.7 per cent occurred between 6pm and 6am.

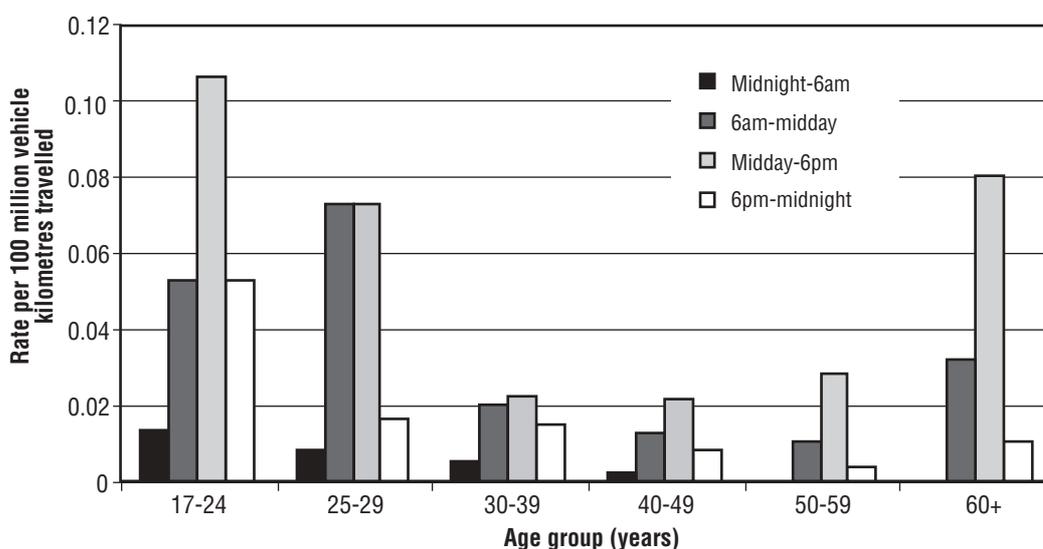
Table 4 shows that fatigued male and female drivers/riders were involved in more head-on crashes between midday and 6pm than during any of the other three periods of the day. No fatigued female drivers/riders were involved in head-on crashes between midnight and 6am.

Table 4:
Fatigued drivers/riders involved in fatal head-on crashes by sex and time of crash, Australia, 1998

Sex	Time of crash				Total
	Midnight-6am	6am-midday	Midday-6pm	6pm-midnight	
Male	6	31	60	17	114
Female	0	12	14	7	33
Unknown	0	4	2	4	10
Total	6	47	76	28	157

Fatigued drivers/riders from every age group (except 25–29 years of age) were involved in more head-on crashes between midday and 6pm than for other periods in the day (see fig. 6). No fatigued driver/rider over 50 years of age was involved in head-on crashes between midnight and 6am.

Figure 6:
Fatigued drivers/riders involved in fatal head-on crashes per 100 million vehicle kilometres travelled^a by time of crash and age, Australia, 1998



^a 100 million vehicle kilometres travelled, 1998, unpublished ABS data

5.7

Articulated truck involvement in fatigue-related crashes

Between 1992 and 1998, 33.5 per cent of articulated truck crashes involved driver fatigue. This is more than double the proportion of non-articulated truck crashes that involved driver fatigue over the same time period (15.1 per cent) (see table 5).

Table 5:
Fatal crashes by articulated truck and fatigue involvement, Australia, 1992 to 1998

Articulated truck involvement	Fatigue		Non-fatigue		Total
	Number	Per cent	Number	Per cent	
Non articulated truck(s)	1129	15.1	6366	84.9	7495
Articulated truck(s)	247	33.5	491	66.5	738
Total crashes	1376	16.7	6857	83.3	8233

For all fatigue-related articulated truck crashes:

- 79.8 per cent involved more than one vehicle
- 62.3 per cent occurred during the day time hours of 6am–6pm (see table 6).

For single vehicle and head-on fatigue-related, articulated truck crashes:

- 72.1 per cent of head on crashes occurred during the daytime
- 76.0 per cent of single vehicle crashes occurred in the early morning (see table 6).

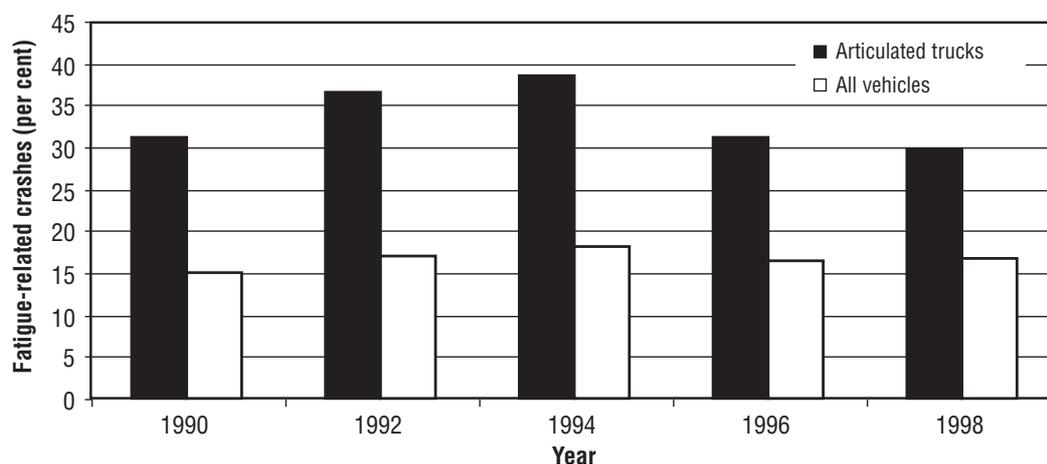
Table 6:
Fatigue-related fatal crashes involving an articulated truck by type of crashes involving an articulated truck by type of crash and time of crash, Australia, 1992 to 1998

<i>Type of crash</i>	<i>Time of crash</i>				<i>Total</i>
	<i>Midnight-6am</i>	<i>6am-midday</i>	<i>Midday-6pm</i>	<i>6pm-midnight</i>	
Single vehicle	38	n/a	12 ^a	n/a	50
Head-on	25	74	68	30	197
Total	63	74	80	30	247

^a 2pm to 4pm only

Between 1990 and 1998, the proportion of articulated truck crashes involving fatigue ranged from a high of 38.6 per cent in 1994 to a low of 29.9 per cent in 1998 (see fig. 7). Figure 7 also shows that the proportion of fatigue-related crashes for articulated trucks was close to double the proportion of fatigue-related crashes for the full range of vehicles.

Figure 7:
Proportion of fatigue-related fatal crashes for articulated trucks and all vehicles, Australia, 1990 to 1998

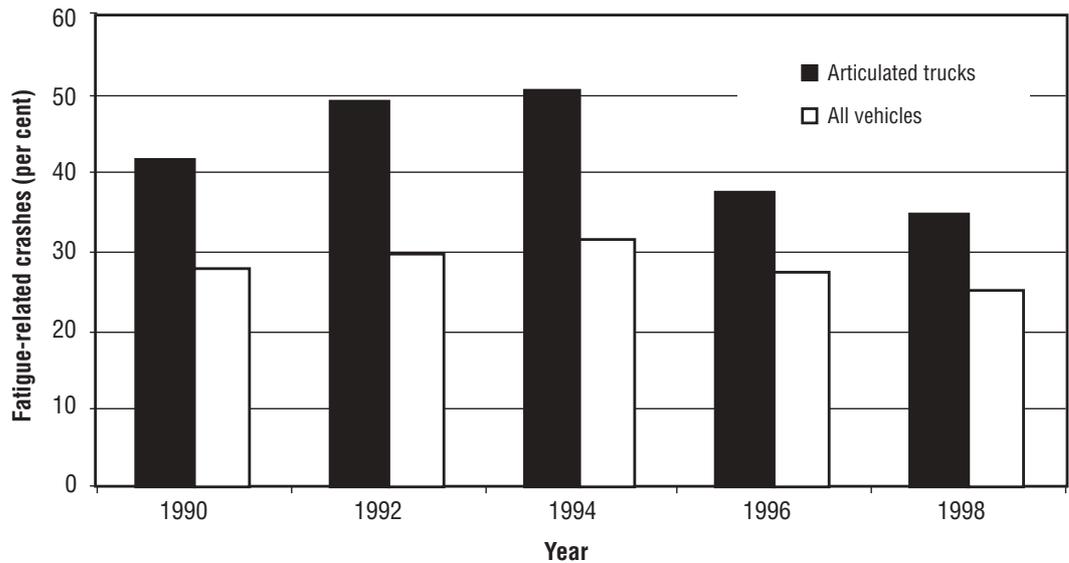


Speed zones were again controlled, for reasons already discussed and because compared with other vehicles articulated trucks are more likely to drive on roads with speed limits of 80km/h and over.

Figure 8 shows that even with speed zones controlled a higher proportion of articulated truck crashes involved fatigue compared with all fatal crashes. However, the difference between fatigue involvement in articulated truck crashes and all vehicle crashes was smaller when speed zones were controlled compared with speed zones not being

controlled. That is, in 1998 when speed zones were not controlled, 29.9 per cent of articulated truck crashes and 16.6 per cent of all crashes involved fatigue (a difference of 13.3 per cent). By comparison, in 1998 when speed zones were controlled, 34.5 per cent of articulated truck crashes and 24.9 per cent of all crashes involved fatigue (a difference of 9.6 per cent).

Figure 8:
Proportion of fatigue-related fatal crashes for articulated trucks and all vehicles for speed zones 80km/h or over, Australia, 1990 to 1998



Whilst between 1992 and 1998, 33.5 per cent of all articulated truck crashes involved driver fatigue, it wasn't necessarily the truck driver that was fatigued. In the 50 single vehicle fatigue-related articulated truck crashes, the truck driver was fatigued. In the 197 head-on fatigued related truck crashes the fatigued driver was identified by observing which vehicle had driven onto the wrong side of the road, and the distribution of fatigued drivers was:

- passenger car drivers (66.0 per cent)
- articulated truck drivers (16.8 per cent)
- rigid truck drivers (5.6 per cent)
- motorcycle riders (1.5 per cent)
- bus drivers (0.5 per cent)
- the fatigued driver could not be identified for the remaining 9.6 per cent of crashes.

5.8 Coronial and police identification of fatigue-related crashes

Of the 1511 fatal crashes in 1998, 46 crashes were identified as fatigue-related by both the operational definition and coroners/police. An additional 53 crashes were identified as fatigue-related only by coroners/police and an additional 205 crashes were identified as fatigue-related by only the operational definition (see table 7).

Table 7:
Matching decisions made by coroners/police and the operational definition in relation to the identification of fatigue involvement in fatal crashes, Australia, 1998

<i>Coroner/Police identification of fatigue involvement in fatal crashes</i>	<i>Operational definition identification of fatigue involvement in fatal crashes</i>		<i>Total</i>
	<i>No fatigue</i>	<i>Fatigue</i>	
No fatigue	1207	205	1412
Fatigue	53	46	99
Total	1260	251	1511

The operational definition identified 205 crashes as being fatigue-related that coroners/police did not. The primary factor contributing to these crashes, according to coroners/police, included:

- unintended driver errors (49 crashes), such as failing to see another road user or condition, a misjudgment of road conditions such as the width of the road, etc.
- drugs and/or alcohol (37 crashes)
- excessive speed (34 crashes)
- unknown circumstances (29 crashes) (see table 8).

Table 8:
Contributory factors determined by coroners/police for crashes identified as fatigue-related by operational definition, Australia, 1998

<i>Contributory factors</i>	<i>Fatal crashes</i>
Fatigue	46
Unintended road user error	
Failed to observe other road user or condition	19
Misjudgment of road condition	26
Other unintended road user error	4
Road user impairment	
Alcohol (blood alcohol concentration less than 0.05g/100ml)	9
Drugs	24
Alcohol and drugs	4
Pre-crash blackout	10
Other road user impairment	6
Deliberate risk or action	
Excessive speed	34
Other dangerous manoeuvre	5
Critical vehicle malfunction	12
Road environment (eg. skid on water, permanent defect on road surface)	12
Weather (eg. vision obscured by rain, gust of wind)	3
An animal stepped out in front of the vehicle	8
Unknown factor	29
Total crashes	251

Coroners/police identified fatigue as a factor in 53 crashes where the operational definition did not. These crashes were not included by the operational definition for a variety of reasons (see table 9). The most common reason for exclusion was single vehicle crashes that occurred during non-critical time periods (34 crashes).

These single vehicle crashes were spread throughout the day:

- sixteen crashes occurred during two hours either side of the early morning critical time period
 - thirteen crashes between 6am and 8am
 - three crashes between 10pm and midnight
- nine crashes occurred two hours either side of the afternoon critical time period
 - five crashes between midday and 2pm
 - four crashes between 4pm and 6pm
- nine crashes occurred throughout the rest of the day.

Eight crashes were excluded solely because they were neither a single vehicle crash nor a head-on collision (see table 9). These crashes included:

- two rear-end collisions
- two collisions with parked cars
- two collisions at intersections
- one collision as a result of a lane change
- one collision involving a vehicle cutting in after overtaking.

**Table 9:
Reasons for excluding crashes identified as fatigue-related by coroners/police from the operational definition, Australia, 1998**

<i>Reason for exclusion</i>	<i>Fatal crashes</i>
Driver/rider with high BAC	0
Unlicensed driver/rider	1
Pedestrian/s involved	0
Speed limit less than 80km/h	7
Single vehicle crash outside critical times	34
Single vehicle crash outside critical times and speed limit less than 80km/h	2
Pedestrian/s involved and speed limit less than 80km/h	1
Neither a single vehicle nor head-on crash (eg. rear-end collision)	8
Total	53

6.1 **Fatigue-related crash trends**

The proportion of fatigue-related crashes identified by the operational definition increased in the early 1990s (between 1990 and 1994) and then decreased in the second half of the 1990s (between 1994 and 1998). This trend was also observed when speed zones were controlled.

One reason for the increase in the proportion of fatigue-related crashes in the early 1990s may be due to a decrease in the number of crashes attributed to other causes such as speeding, alcohol, and so forth. Therefore whilst the actual number of fatigue-related crashes remained relatively static, the proportion of fatigue-related crashes increased as the overall number of fatal crashes decreased.

The decrease in the proportion of fatigue-related crashes in the latter part of the 1990s might be due to an increased awareness of fatigue and fatigue-related countermeasures. Such countermeasures include public education (including television advertisements), engineering of road environment to be more forgiving (including profile line markings, divided roads, removal of roadside hazards such as poles), provision of rest stops, and so forth.

6.2 **Fatigue-related crash characteristics**

The operational definition identified more fatigue-related head-on crashes than single vehicle crashes, and the incidence of head-on fatigue-related crashes was highest between midday and 6pm and lowest between midnight and 6am. On the other hand, a higher number of fatigue-related single vehicle crashes occurred in the early morning (midnight–6am) than in the afternoon (2pm–4pm). The relationship between time of crash, number of vehicles involved and the frequency of fatigue-related crashes may be a result of changing traffic densities throughout the day and night. That is, whilst the risk of fatigue is lower during the day there is more traffic on the road which reduces the opportunity fatigued drivers have to correct their driving, after drifting onto the wrong side of the road, before colliding with another vehicle. Thus, higher traffic density during the day increases the number of fatigue-related crashes and the likelihood of a collision involving multiple vehicles. The risk of a crash involving a fatality is also increased when two vehicles are involved. Therefore, traffic densities may explain why most fatigue-related fatal crashes involved multiple vehicles and occurred during the day, even though the risk of fatigue is lower than during the night and early morning.

This study and other studies (eg. the EPDFS (1997) and Knipling and Wang (1994)) have reported similar findings with respect to the age and sex of fatigued drivers. For example, the operational definition identified a higher number of fatigued male drivers/riders than female drivers/riders. The operational definition also identified a higher number of fatigued drivers/riders under 29 years of age compared with other age groups. In the early morning, fatigued drivers/riders tended to be under 29 years of age, and fatigued drivers/riders over 50 years of age were involved in more afternoon crashes than early morning crashes.

This study also looked at whether there was any relationship between the age of the fatigued driver/rider and the type of crash (single vehicle or head-on). The operational definition found that compared with head-on crashes, single vehicle crashes involved a higher proportion of fatigued drivers/riders under 29 years of age. Whereas fatigued drivers/riders over 50 years of age were involved in more head-on crashes. This relationship may be linked to the time of crash. That is, single vehicle crashes are more likely to occur in the early morning and early morning crashes are more likely to involve fatigued drivers/riders under 29 years of age. Therefore single vehicle crashes involve more fatigued drivers/riders under 29 years of age. A similar argument could explain the relationship between older fatigued drivers/riders and head-on crashes.

According to the operational definition, fatigue was a factor in twice the proportion of articulated truck crashes compared with non-articulated truck crashes between 1992 and 1998. During this period, fatigue-related crashes rose between 1990 and 1994, after which there was a turn around till 1998. Therefore, this report reinforces the notion that fatigue is still an important safety issue for the freight transport industry to address, and while the proportion of fatigue-related articulated truck crashes decreased between 1994 and 1998, it was still higher than the overall proportion of fatigue-related crashes even when speed zones were controlled.

While trucks are involved in a relatively high proportion of fatigued related crashes, they are not necessarily the fatigued driver responsible for the crash, especially in head-on crashes. That is, truck drivers were estimated to be the fatigued driver in 16.8 per cent of head-on crashes and passenger car drivers were fatigued in 66.0 per cent of crashes.

As with all fatigue-related crashes identified by the operational definition, most crashes involving an articulated truck were found to have involved multiple vehicles and to have occurred during the daytime (6am to 6pm). However, when an articulated truck was the sole vehicle involved, most crashes occurred during the early morning. Again, changing traffic densities throughout the day and night might have affected the frequency, time and type of fatigue-related crashes.

6.3 The operational definition of fatigue

Whilst the operational definition is not designed to measure the absolute number of fatigue-related crashes, but rather an index of the relative incidence of fatigue-related crashes, it is helpful to assess whether the underlying selection rules are adequate in identifying likely fatigue-related crashes. To address this concern, this study compared crashes identified as fatigue-related by coroners/police with fatigue-related crashes identified by the operational definition. As previously mentioned, identification of fatigue by coroners/police is conservative; however, this was the only measure available with which to compare the operational definition.

Some of the 205 fatal crashes identified as fatigue-related by the operational definition, but not by coroners/police, may have actually involved fatigue. That is, for 38.0 per cent of these crashes, the contributory factor (determined by coroners/police) was unknown or involved an unintended driver error (inattention, misjudgment, etc). Coroners/police incline towards conservatism when unsure whether or not fatigue was involved, and consequently indicate the contributory factor as unknown if no other factor was involved. Also, driver inattention and other unintended errors are often due to fatigue, as research has shown that fatigue affects performance on attention based tasks (HORSCOCTA, 2000). However, coroners again tend to be conservative if they are

unsure whether inattention or unintended errors were due to fatigue. Thus, coroners may have attributed the crash to an unintended driver error if there was not enough evidence to suggest that the inattention was due to fatigue, or to an unknown factor if there was insufficient evidence that the driver had been asleep prior to the crash.

However, a large proportion of the 205 crashes cannot be explained by lack of evidence. For example, coroners/police identified drugs and/or alcohol, or excessive speed to be a contributory factor in 34.6 per cent of these crashes. These results may highlight a limitation and a potential modification for the operational definition as it does not exclude drug or speed related crashes. However, the identification of speed involvement may vary between different traffic authorities and it would therefore be a potential source of bias to remove these crashes from the analysis. Identification of drivers influenced by drugs (excluding alcohol) is also problematic as not all drivers involved in fatal crashes are tested for drugs. Therefore, the removal of either drug or speed related crashes would reduce the objectivity of the operational definition and its ability to be consistently implemented across different crash databases within Australia and overseas. This is an area where further research could bring about some modification in the operational definition of fatigue.

Some 53 fatal crashes identified by coroners/police as involving fatigue were not picked up by the operational definition. Analysis of these crashes indicates that the time limitation of single vehicle crashes to early morning (midnight to 6am) and mid-afternoon (2pm to 4pm) may have been overly restrictive. That is, the results show that most of the 53 crashes were excluded because they were single vehicle crashes outside the 'critical time' periods, and that three-quarters of these single vehicle crashes occurred within two hours either side of the critical time periods. Thus these results could reflect a need to extend the critical time periods. On the other hand, extending the time periods could potentially lead to an increase the number of crashes falsely identified as fatigue-related. More analysis is necessary before the time periods could be confidently extended.

The operational definition may to some extent underestimate the incidence of fatigue-related crashes. This study found that 16.6 per cent of all fatal crashes involved fatigue; this was slightly lower than the 20 per cent to 30 per cent of fatal crashes that most experts believe involve driver fatigue (HORSCOCTA, 2000). However, the operational definition's estimation is closer to the expected percentage compared with coroners/police reporting, which was seven per cent of all fatal crashes in 1998.

One reason why the operational definition may underestimate the incidence of fatigue-related crashes could be that other research overestimates the incidence of fatigue by attributing fatigue as a cause of a crash when the cause is unknown. That is, in the absence of other causal factors, the crash may be attributed to fatigue. On the other hand, the operational definition may underestimate the incidence of fatigue because other research used methods that had access to more detailed information regarding driver fatigue. Such methods may include self-reported driver surveys, fatigue-related measurements obtained from laboratory experiments (eg. lane tracking tasks) and on-road research (eg. facial video monitoring). Other research may have used more detailed crash investigation reports. Such reports could provide additional information regarding the time spent driving, the amount of sleep the driver had the previous night, eye witness accounts regarding the driver's behaviour prior to the crash (eg. drifting between lanes) and other information that is not routinely collected. This additional information

obtained from other sources reflects a limitation of the operational definition. It is well known that time spent driving, amount of sleep and time of day are the three main determinates of fatigue (Hartley, Penna, Corry and Feyer, 2000; Williamson, Feyer, Friswell and Finlay-Brown, 2000), however, the operational definition includes only the time of day determinant. The reason for excluding time on task and amount of sleep is that most road crash databases are based on police reports and police do not routinely collect this information after a crash. Even if police changed their routine reporting it may still be difficult as there are often no surviving witnesses to provide this information and surviving drivers may be influenced by the legal consequences of the crash.

While the operational definition possesses some limitations and will inevitably fail to identify some fatigue-related crashes and include some crashes caused by other factors, the operational definition is, at the moment, the most useful tool for objective comparisons. That is, the definition is useful for monitoring the incidence of fatigue-related crashes over time, comparing fatigue-related rates for different locations (States/Territories, Local Government Areas), roads, drivers/riders or vehicles. It may be that coronial and police fatigue identification should be included in addition to surrogate measures similar to New South Wales, Queensland and Western Australia practices (see Appendix A). However as McFadden (1999) and Buxton, Hartley and Buxton (2001) noted, police procedures for identifying fatigue are problematic. Therefore, for consistency and objectivity, fatigue must be inferred from the crash circumstances and characteristics.

In conclusion, this study suggests that the operational definition provides a practical and useful index of the relative incidence of fatigue-related crashes.

Dr Michael McFadden is acknowledged as the primary author of the ATSB operational definition of fatigue.

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APPENDIX A

State/Territory fatigue-related crash definitions

In New South Wales a crash is assessed as being fatigue-related if:

- The vehicle's controller was described by police as being asleep or drowsy; and/or
- The vehicle performed a manoeuvre which suggested loss of concentration of the controller due to fatigue, that is
 - The vehicle travelled onto the incorrect side of a straight road and was involved in a head-on collision (and was not overtaking another vehicle and no other relevant factor was identified; or
 - The vehicle ran off a straight road or off the road to the outside of a curve and the vehicle was not directly identified as travelling at excessive speed and there was no other relevant factor identified for the manoeuvre.

In Queensland a crash is assessed as being fatigue-related if:

- A single vehicle crashes in 100km/h or higher speed zone during typical fatigue times (2pm–4pm or 10pm–6am); or
- The reporting officer considered that fatigue was a contributory factor in the crash.

In Western Australia a crash is assessed as being fatigue-related if:

- Police or the driver, stated that fatigue was a likely cause;
- A vehicle travelled to the incorrect side of the road and was involved in a head-on collision while not overtaking another vehicle; or
- The vehicle ran off the carriageway and the vehicle was not directly identified as travelling at excessive speed and there were no other factors identified as causing loss of control (eg. alcohol, road condition, tyre blow-out, sun glare, side wind, headlights, driver condition, broken screen).

In Victoria, driver fatigue is defined as the involuntary and progressive withdrawal of attention from road and traffic demands. There is no surrogate measure based on time of occurrence or type of crash although witness accounts, especially in fatal crashes, are used to identify fatigue-related crashes.

In Tasmania, fatigue statistics are based on police reporting of inattentiveness or of the driver allegedly being drowsy or falling asleep.

In South Australia, the Northern Territory and the Australian Capital Territory, fatigue statistics are based on police reports.

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